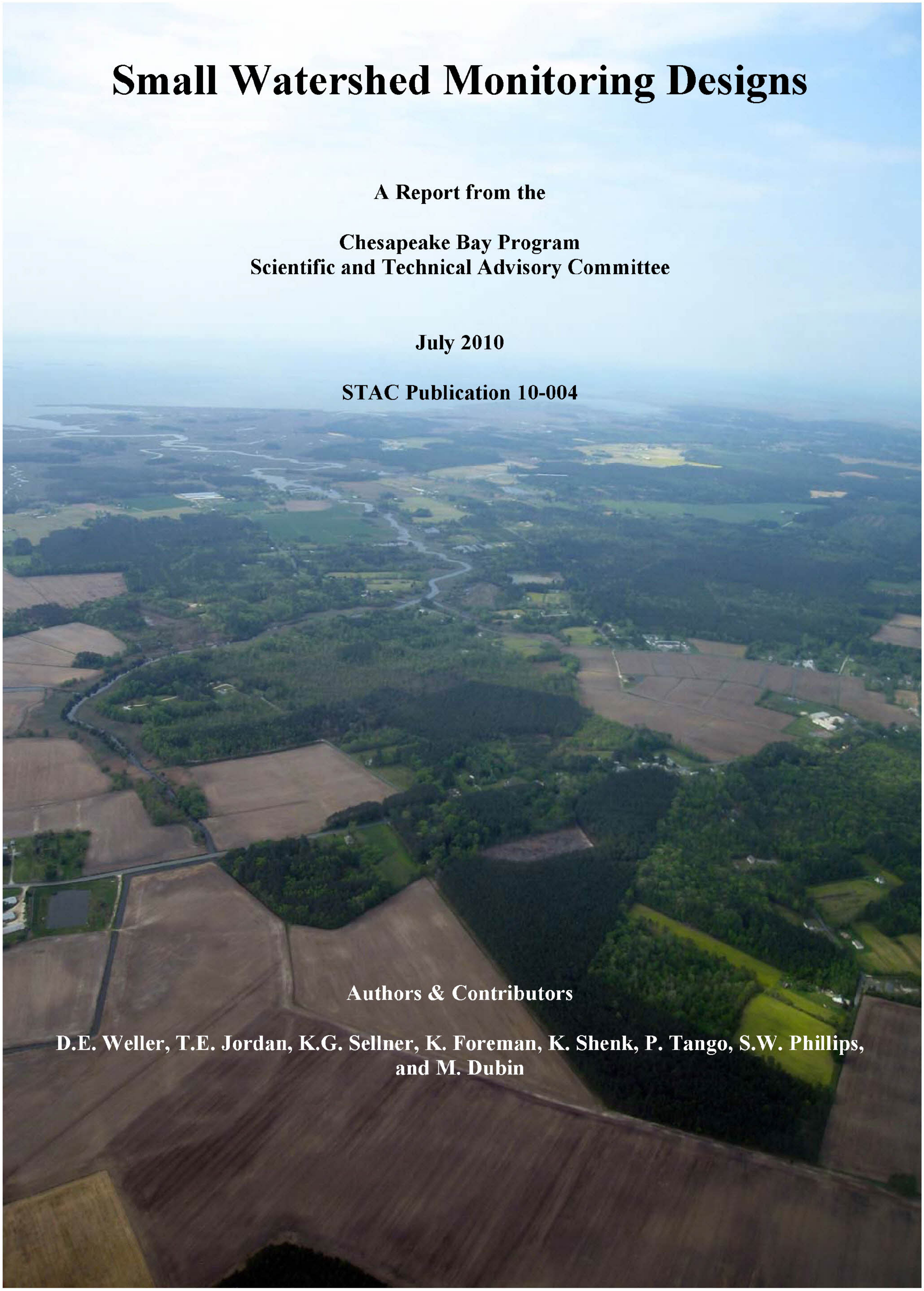

Small Watershed Monitoring Designs

A Report from the

Chesapeake Bay Program
Scientific and Technical Advisory Committee

July 2010

STAC Publication 10-004

Authors & Contributors

D.E. Weller, T.E. Jordan, K.G. Sellner, K. Foreman, K. Shenk, P. Tango, S.W. Phillips, and M. Dubin

About the Scientific and Technical Advisory Committee

The Scientific and Technical Advisory Committee (STAC) provides scientific and technical guidance to the Chesapeake Bay Program (CBP) on measures to restore and protect the Chesapeake Bay. As an advisory committee, STAC reports periodically to the Implementation Committee and annually to the Executive Council. Since its creation in December 1984, STAC has worked to enhance scientific communication and outreach throughout the Chesapeake Bay watershed and beyond. STAC provides scientific and technical advice in various ways, including: (1) technical reports and papers, (2) discussion groups, (3) assistance in organizing merit reviews of CBP programs and projects, (4) technical conferences and workshops, and (5) service by STAC members on CBP subcommittees and workgroups. In addition, STAC has mechanisms in place that allow it to hold meetings, workshops, and reviews in rapid response to CBP subcommittee and workgroup requests for scientific and technical input. This capability allows STAC to provide the CBP subcommittees and workgroups with the necessary information and support as specific issues arise in working towards the goals outlined in the *Chesapeake 2000* agreement. STAC also acts proactively to bring the most recent scientific information to the Bay Program and its partners. For additional information, please visit the STAC website at *www.chesapeake.org/stac.*

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Executive Summary

The Chesapeake Bay Program's Scientific and Technical Advisory Committee (STAC) recommends activities that could reduce nutrient and sediment loads to the Bay. In the recent Farm Bill and its Chesapeake Bay Water Plan, $188M was allocated for implementing agricultural conservation practices beyond those funded by on-going USDA or state programs. STAC saw this commitment as a unique opportunity to demonstrate the effects of conservation practices on water quality.

Although the new funding is significant, the effects on water quality will be difficult to measure if the practices are distributed equitably across the Bay's agricultural lands. Therefore, U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS), Chesapeake Bay Program (CBP) staff, U.S. Geological Survey (USGS), and several research organizations (University of Maryland Center for Environmental Science, the Smithsonian Environmental Research Center, and the Chesapeake Research Consortium) have cooperated to identify areas where nutrient and sediment yields are high and where focused conservation practices would reduce nutrient discharges. STAC agreed to review research and monitoring activities in the region and recommend appropriate monitoring strategies that could document the water quality impacts of focused conservation practices. Through a series of workshops and meetings, STAC and its partners have distilled the following recommendations for monitoring small watersheds to document practice effects on nutrient delivery to Chesapeake Bay. The recommendations are supported by the facts and observations that were discussed among the experts and stakeholders attending the workshops. Those observations are presented in a second list following the recommendations.

Monitoring Recommendations:

1. Study the effects of conservation practices in watersheds that discharge relatively high amounts of agricultural nutrients to Chesapeake Bay.
2. Focus on measuring agricultural nitrogen inputs and discharges.
3. Study smaller watersheds (10 - 40 km^2) within the larger areas of high agricultural impact.
4. Combine estimates of agricultural conservation practice effects, current agricultural activities, and expected levels of new practice implementation to calculate the likely benefits of the new practices. Use these simple calculations (or more sophisticated models) to inform watershed selection and monitoring strategy.
5. Make a long-term commitment (5 - 10+ yr) to four essential tasks in all study watersheds: maintaining conservation practices, assembling and sharing spatially explicit data on conservation practices and other agricultural activities, watershed monitoring, and data analysis.
6. Seek innovative multi-agency and organization arrangements to overcome institutional and legal barriers to assembling and sharing data on conservation practices and agricultural activities.
7. To quantify effects on nitrogen discharge, use inexpensive, low-frequency (e.g., quarterly) sampling of baseflow nitrate from many study watersheds selected to represent a wide range of levels of conservation practices. Compare neighboring watersheds within each physiographic province of the Chesapeake basin.

8. To quantify effects on phosphorus and sediment discharge, use continuous automated water quality monitoring to capture the important effects of episodic high flows. To limit the number of watersheds studied by this costly method, sample a few well-studied watersheds before and after significant new practice implementation can be achieved or sample a few paired watersheds where significant new implementation can be directed to experimental watersheds AND excluded from control watersheds. Either approach requires funding for automated monitoring and high ability to direct the implementation of conservation practices.
9. Build partnerships within the study watersheds to implement and maintain the conservation practices, to collect data on conservation practices and agricultural activities, and to conduct the watershed monitoring.
10. Build partnerships to coordinate among study watershed efforts and to analyze and interpret resulting data.
11. The watershed monitoring program should focus on documenting the effects of the implemented mixtures of conservation practices on stream nutrient transport. Detailed questions about specific conservation practices or specific mixes of conservation practices should be addressed through specific rigorously defined research efforts at the sites of practice implementation, and not through watershed monitoring.

Supporting Facts and Observations:

1. Watershed models such as the USGS **SPA**tially **R**eferenced **R**egressions **O**n **W**atershed attributes (SPARROW) can be used to identify large areas that are most in need of conservation practices to reduce high nutrient and sediment loadings to Chesapeake Bay. Focusing new conservation practices to smaller study watersheds (10 - 40 km^2) within these large areas will increase the chances of demonstrating water quality responses.
2. To interpret the effects of the conservation practices on nutrient discharges, watershed monitoring alone is not sufficient. It will be necessary to collect detailed data on the practices and other agricultural activities that affect nutrient discharges, including: areas, spatial distribution, and types of agricultural lands (croplands, pastures, etc.); fertilizer application rates; livestock populations; and the locations of riparian buffers and wetlands.
3. Obtaining and maintaining the data on conservation practices and agricultural activities may be harder and more costly than the water quality monitoring. There are significant logistical, institutional, and legal barriers to assembling and sharing these data.
4. Study watersheds will receive complex mixtures of conservation practices that have different effects on nutrient loads. Summing the monetary costs of the practices in each watershed can estimate the total conservation effort for use in comparing conservation effort and nutrient discharges among watersheds.
5. Long-term (5 - 10+ year) commitments are needed because of lags between implementation and discharge responses. The long-term commitment has four components: keeping practices in place, assembling and sharing the data on implementation and agricultural activities, monitoring the water quality response, and analyzing and interpreting the results.
6. Three approaches were identified to quantify the effects of conservation practices on water quality. 1) Watershed discharges can be compared before and after implementation of conservation practices. This requires monitoring discharges long enough to account for temporal variability unrelated to the conservation practices. Using watersheds that have already been monitored for 5 -10 years could eliminate the delay from collecting the "before" data. Also, the lag time between implementation and discharge response could provide some

baseline measurements. 2) Compare discharges from pairs of similar watersheds, one with and one without conservation practices. This requires finding well-matched watersheds and maintaining the contrasting levels of conservation practices long enough to observe differences in discharges attributable to the practices. 3) Compare discharges from numerous watersheds that differ widely in their levels of conservation practices and look for correlations between discharge rates and the level of conservation practice. This approach requires less monitoring time than before-and-after sampling and less control of conservation practices than paired comparisons, but it also requires monitoring more watersheds. With all of these approaches, it is necessary to account for many other factors influencing discharges, such as intensities of various agricultural activities, to infer the effects of conservation practices.

7. Changes in nitrogen (N) concentrations can be estimated with inexpensive seasonal baseflow sampling of nitrate concentrations. Dissolved nitrate is the main form of N released from N-enriched watersheds, and seasonal measurements are sufficient because stream nitrate concentrations are relatively constant. Streamflow discharge should be estimated within the study watersheds or from measurements in nearby monitored watersheds. Nitrogen is especially important because it is the limiting nutrient in most times and places in tidal Chesapeake Bay.
8. Baseflow nitrate sampling can be applied cost effectively to many watersheds with differing rates of practice implementation. This option will be especially important if it is not possible to strongly direct practice implementation. In that case, numerous watersheds can be selected after implementation to give a set of study watersheds with widely different implementation rates of new practices (including watersheds with little or no new implementation).
9. Phosphorus discharges are harder to measure than nitrogen discharges because phosphorus is carried mainly on suspended particles. Particle concentrations are quite variable, and a few short episodes of high storm flow can account for much of the annual phosphorus discharge. Continuous monitoring that captures both high and low flows is needed to measure phosphorus and sediment discharges, but it may be too expensive to undertake in many watersheds. Therefore, approaches that limit the number of watersheds to be monitored (such as before-and-after monitoring or paired comparisons) might be more suitable for automated sampling.

These STAC recommendations should inform the monitoring efforts that will be established within the high nutrient and sediment yield areas recently identified for each state by its NRCS State Technical Committees. We especially emphasize that access to high-resolution data on practice implementation, land use, crop production, fertilizer/manure application, and other agricultural activities are essential to the effort. Without this information, monitoring water quality to detect interpretable improvements will be unproductive. Basin-wide cooperation and participation must become the standard operating procedure for this assessment to succeed.

Introduction

Over three decades of effort to improve water quality in the Bay's watershed have produced relatively modest reductions in nutrient and sediment loads through voluntary partnerships among governments, other organizations, and citizens. Most of the reductions can be attributed to point source discharge reductions imposed by regulatory constraints implemented though discharge permits. Non-point source loads remain problematic because voluntary programs in the agriculture community have not been effective and population growth has increased loads from expanding suburban and urban areas.

In the last two years, new Federal agency and state commitments to restoring water quality across the Chesapeake Bay watershed pose excellent opportunities for dramatic reductions in nutrients and sediments entering our waterways. At the Federal level, the 2008 Farm Bill provides $188 M for increasing conservation practice implementation in the Basin over five years. State-sponsored focused implementation has also occurred, such as the 2010 Trust Fund, the Corsica River restoration effort, the fall cover crop program in Maryland, and Pennsylvania's commitment to restoring the Conewago River watershed in the southeastern portion of the state. The Farm Bill presents a unique opportunity to quantify watershed responses from implementation of new conservation practices. Well-placed and well-documented practice implementation can be combined with appropriate water quality monitoring. Demonstrating the water quality benefits of new practices could motivate future investments in conservation that would expand benefits to Chesapeake Bay and its tributaries. However, the Farm Bill funds cannot be spent on monitoring the impacts of the implemented conservation practices on water quality. Having a well-designed monitoring plan for detecting water quality responses would help in seeking other funding for the needed monitoring.

The Chesapeake Bay Program's (CBP) Scientific and Technical Advisory Committee (STAC) recommends activities that could reduce nutrient and sediment loads to the Bay. STAC saw the Farm Bill commitment to implementing conservation practices as a unique opportunity to demonstrate the effects of these practices on water quality. STAC sponsored a series of technical and stakeholder meetings in 2009 to seek community ideas on a monitoring plan that would maximize the possibility of detecting water quality improvements from the enhanced implementation programs. This report summarizes the resulting STAC recommendations for small watershed monitoring programs and the information supporting those recommendations.

STAC Workshops

The STAC funded two workshops to engage researchers and watershed stakeholders and to recommend monitoring designs for small watersheds where conservation practices might be implemented at high intensities. The STAC workshops were motivated by the Farm Bill and focused on agricultural watersheds, but the resulting recommendations for watershed targeting and monitoring presented are relevant to monitoring small watersheds dominated by other land uses as well.

The first workshop and post workshop synthesis was held April 23-24, 2009 at the USGS Water Science Center on the UMBC Campus. The goal of the first workshop was to develop effective monitoring designs to quantify nutrient and/or sediment reductions from accelerated agricultural conservation practice implementation. The workshop had technical presentations and discussions of water monitoring approaches and the conditions that would maximize the likelihood of detecting water quality response to conservation practices. Scientists presented 'lessons learned' from previous monitoring projects in agriculturally dominated watersheds. Open discussion was encouraged.

A second workshop was held on May 28, 2009 at the USGS Center. The goals were to develop a short list of small watersheds in the Chesapeake Bay Watershed to monitor and outline next steps for implementing a monitoring strategy. The monitoring recommendations from the first workshop were presented to representatives from agricultural agencies, non-governmental organizations (NGOs), and the staff of current monitoring projects. Additional criteria were identified to assist in narrowing watershed selection.

Since the workshop, the steering committee has distilled a set of recommendations for the monitoring program. These are presented first, followed by the information from the workshops that support the recommendations:

Monitoring Recommendations

1. *Study the effects of conservation practices in watersheds that discharge relatively high amounts of agricultural nutrients to Chesapeake Bay.*
2. *Focus on measuring agricultural nitrogen inputs and discharges.*
3. *Study smaller watersheds (10 - 40 km^2) within the larger areas of high agricultural impact.*
4. *Combine estimates of agricultural conservation practice effects, current agricultural activities, and expected levels of new practice implementation to roughly calculate the likely benefits of the new practices. Use these simple calculations (or more sophisticated models) to inform watershed selection and monitoring strategy.*
5. *Make a long-term commitment (5 - 10+ yr) to four essential tasks in all study watersheds: maintaining conservation practices, assembling and sharing spatially explicit data on conservation practices and other agricultural activities, watershed monitoring, and data analysis and interpretation.*
6. *Seek innovative multi-agency and organization arrangements to overcome institutional and legal barriers to assembling and sharing data on conservation practices and agricultural activities.*
7. *To quantify effects on nitrogen discharge, use low-frequency (e.g., quarterly) sampling of baseflow nitrate from many study watersheds selected to represent a wide range of levels of conservation practices. Compare neighboring watersheds within each physiographic province.*
8. *To quantify effects on phosphorus and sediment discharge, use continuous automated water quality monitoring to capture the important effects of episodic high flows. To limit the number of watersheds studied by this costly method, sample a few well-studied watersheds before and after significant new practice implementation can be achieved or sample a few paired watersheds where significant new implementation can be directed to experimental watersheds AND excluded from control watersheds. Either approach requires funding for*

automated monitoring and high ability to direct the implementation of conservation practices.

9. *Build partnerships within the study watersheds to implement and maintain the conservation practices, to collect data on conservation practices and agricultural activities, and to conduct the watershed monitoring.*
10. *Build partnerships to coordinate among study watershed efforts and to analyze and interpret resulting data.*
11. *The watershed monitoring program should focus on documenting the effects of the implemented mixtures of conservation practices on stream nutrient transport. Detailed questions about specific conservation practices or specific mixes of conservation practices should be addressed through specific rigorously defined research efforts at the sites of practice implementation, and not through watershed monitoring.*

Focus on High Nutrient Yield Areas

Although the new funding is significant, the effects on water quality would be difficult to measure if the practices were distributed equitably across the Bay's agricultural lands. Before the STAC workshops, the staffs from the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS), CBP, U.S. Geological Survey (USGS), and University of Maryland Center for Environmental Science (UMCES) had already met over a six month period to discuss and prioritize agriculturally-dominated areas for high implementation of conservation practices. Criteria used in selecting these priority watersheds included nitrogen and phosphorus yields to the Bay, listings of impaired waters, likely conservation practice implementation, and pre-existing monitoring programs. Largely using the USGS SPARROW watershed model, nutrient yield 'hot spots' were identified in each state (Fig. 1). These were selected as possible recipients of Farm Bill funds over and above the routine baseline implementation funding provided in the annual NRCS programs in each state. The idea to focus conservation practice funding in some watersheds was a groundbreaking departure from the historical commitment to equitable distribution of implementation funding across the basin.

Small Watershed Studies

Small watershed studies provide the best opportunities to assess the effectiveness of conservation practices and to understand the multiple factors affecting water quality change. The agriculturally-dominated watersheds selected in the initial screening (Fig. 1) are large and contain other important nutrient sources besides agricultural activities. These include some suburban and urban areas with diffuse source areas (impervious surfaces, septic systems, and storm water systems), point sources (waste water treatment plants), industrial sources, and others. Technical experts recommended that implementation be further focused to achieve high levels of implementation in small watersheds even more strongly dominated by agricultural activities. With small watersheds, it is possible to identify (or create) distinct combinations of agricultural activities and conservation practices, while larger watersheds tend to be more uniform. The workshop participants agreed that watersheds between 10 and 40 km^2 in area would be optimal.

Chesapeake Bay watershed managers are interested in assessing the management effectiveness at regional to local scales. Regional water quality patterns are well captured by the existing Chesapeake Bay Program monitoring network. Extending that network to include small watersheds as described here is critical for maximizing opportunities to assess effectiveness of management actions on Bay water quality.

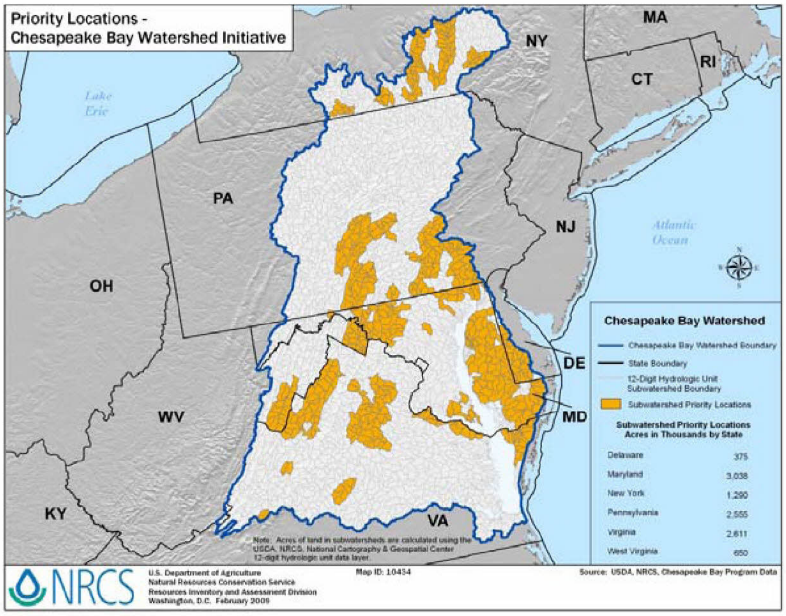

Figure 1. Priority watersheds for focused NRCS conservation practice implementation.

Need for Information on Conservation Practices and Agricultural Activities

To infer the effects of the conservation practices on water quality, detailed data on the agricultural activities and the conservation practices in the study watersheds will be needed. Assembling these data is just as important as monitoring water quality responses. Information on the numbers, types, and locations of conservation practices are obviously essential (Table 1).

Table 1. Information on conservation practices needed for every study watershed.

Dollars spent on new conservation practices
Acres of cover crop
Mapped coverage of riparian buffer restorations
Mapped coverage of wetland restorations
Change in N and P fertilizer applications to croplands
Change in rates and timing of manure application
Changes in manure management

Less obvious, but just as important, is information on agriculture in general, including the areas, spatial distribution, and types of agricultural lands (croplands, pastures, etc.); fertilizer application rates; livestock populations; and other factors (Table 2). Data on the spatial distribution of riparian buffers and wetlands are also important because these ecosystems can affect nutrient discharges, and their restoration may be among the conservation practices aimed at reducing nutrient loads. Observed changes in water quality cannot clearly be attributed to changes in the level of conservation practice implementation unless we can quantify changes in other factors (Table 2) that might also have caused water quality changes.

Table 2. Other information on agricultural activities that must also be collected for every study watershed. The items are roughly arranged in priority order, with items higher on the list likely having stronger effects on water quality.

Acres of cropland
Acres of specific crop types
Fertilizer N and P application rates
Populations of livestock by type of livestock
Manure application rates
Mapped coverage of previously existing riparian buffers and wetlands
Acres of pasture land
Intensity of pasture land use
Tillage practices

The information on conservation practice implementation in each watershed must include the total monetary cost of all the practices implemented. This information can serve two purposes. It can provide a crude representation of the implementation effort if spatially explicit information on individual practices (Table 1) is not available. Secondly, study watersheds will receive complex mixtures of conservation practices that have different effects on nutrient loads. Cost provides a common metric for estimating the total effort from different practices that have different effects or units of measure so they cannot be directly combined.

Accurate information on agricultural activities and implementation of new practices must be available for the exact small watersheds that will be studied. Data summaries for counties, for larger watershed (e.g., HUC8), or for small watersheds that may not correspond with monitoring points (e.g., HUC12), will not suffice.

Collecting and maintaining these critical data may be more difficult and costly than monitoring the nutrient discharges from the watersheds. There are significant logistical, institutional, and legal barriers to assembling and sharing these data. Partners must continue to work with NRCS (and state implementation agencies) to access needed agricultural and implementation data given the confidentiality restrictions outlined in Section 1619 of the Farm Bill and other access limitations. On-going discussions among NRCS and its partners in responding to the recent Presidential Executive Order may produce a process for collecting and using these critical data. USDA is attempting to resolve this issue by negotiating for data access through USGS.

Need for Long-term Effort

There must be a long-term (5 - 10+ year) commitment to the monitoring program because of the lag time between implementation and discharge responses. The long-term commitment has four components: keeping practices in place, assembling and sharing the data on implementation (Table 1) and agricultural activities (Table 2), monitoring the water quality response, and analyzing and interpreting the results

Long-term discharge monitoring is necessary because of the time it takes for groundwater to flow from beneath crop fields or other source areas to streams. In most areas, the majority of the nitrogen discharged from agricultural watersheds is carried in groundwater as dissolved nitrate. Conservation practices, such as cover crops, that reduce the leaching of nitrate from crop fields into groundwater will not produce a measureable effect on stream water until the groundwater reaches the stream. Conservation practices, such as riparian buffer restoration, that remove nitrate from groundwater as it is reaching the stream might have a more immediate effect on stream water nitrate, but there could still be time delays while the vegetation and soils of the restored system recover. Therefore, short-term monitoring is not a viable option.

Many of conservation programs are implemented through 1 - 3 year contracts. Additional effort will be needed to maintain agricultural conservation practices for the even longer time period (5 - 10+ years) needed to detect water quality responses.

Watershed Monitoring Approaches

There are three main choices for measuring the water quality effects of conservation practices (for a review, see NRCS 2003). First, watershed discharges can be compared before and after implementation of conservation practices. A second method is to compare discharges from pairs of similar watersheds, one with and one without conservation practices. A third approach compares discharges from numerous watersheds that differ widely in their levels of conservation practices. Each approach has strengths and limitations, and the optimal approach depends on the degree of control over practice implementation and the funding available to support watershed monitoring. With all of these approaches, it is necessary to account for many other factors influencing discharges, such as intensities of various agricultural activities, to infer the effects of conservation practices.

One problem with before/after comparisons in a single watershed is that year-to-year variability in climate, runoff, and agricultural activity confounds changes in watershed discharge caused by implementing the conservation practice. This requires monitoring discharges long enough to account for temporal variability unrelated to the conservation practices. However, focusing on a watershed that has already been monitored for 5 - 10 years could eliminate the delay from collecting the "before" data. Also, the lag time between implementation and discharge response could provide some baseline measurements.

The paired watershed approach requires finding of well-matched watersheds and maintaining the contrasting levels of conservation practices for sufficient time to observe differences in discharges attributable to the practices. The two small watersheds should have similar geologies, topographies, and land uses, as well as landowners receptive to a long-term study. Private owner cooperation for long periods requires effective outreach in both watersheds prior to and during the study, and landowner compliance may change with crop prices, fertilizer costs, or other pressures. Incentives for land owner cooperation were critical to a paired watershed study in the Pocomoke basin, which reported a 30% decrease in total nitrogen discharge over four years in the watershed with high levels of nutrient control compared to the watershed lacking nutrient controls (McCoy 2009). Because only two watersheds were monitored, a complete (but costly) suite of stream measurements was feasible. However, non-compliance on agreed land uses by some land owners may have limited the observed response (McCoy 2009).

The third approach compares discharges from numerous watersheds that differ widely in their levels of conservation practices and tests for correlations between discharge rates and the level of conservation practice implementation. This approach requires less monitoring time than before-and-after sampling and less control of conservation practices than paired comparisons, but it requires monitoring more watersheds. Weller et al. (2009) used this approach in a study of the effects of riparian buffers on stream nitrate concentrations. Hundreds of watersheds with a broad range of existing riparian buffer extents were selected from three major physiographic provinces of the Chesapeake watershed. The effects of buffers on water quality were inferred by using statistical models to relate measured stream nitrate concentrations to metrics quantifying the prevalence of buffers in each watershed. By considering many watersheds, it was possible to include watersheds with very low levels of conservation effort (riparian buffers) and watersheds with very high levels. The study also considered neighboring watersheds within the same physiographic province to accommodate major differences in nutrient release from croplands in different provinces (Jordan et al. 1997).

If a high degree of implementation into a few specific monitored watersheds as part of a designed experiment can be assured, then a monitoring strategy more like the McCoy (2009) paired watershed study should be followed. At the other extreme, if there is only relatively opportunistic implementation of conservation practices across many watersheds, then the strategy of studying many watersheds with a wide range of implementation would be a better approach. The choice of strategy is also influenced by the most effective ways to measure different nutrients (below) and the money available to support monitoring.

Measuring Changes in Nitrogen and Phosphorus

Nitrogen and phosphorus are the most important nutrients to regional aquatic productivity, and excessive loads of these two elements have led to euthrophication of the Chesapeake Bay. Nitrogen is the limiting nutrient in most of the Bay most of the time. Nitrogen and phosphorus are transported in different ways. Dissolved nitrate is the main form of nitrogen released from nitrogen-enriched watersheds, and dissolved nitrate is transported to streams mainly by subsurface flows (Jordan et al. 1997, Sutton et al. 2009). In contrast, phosphorus is transported mainly on particles in surface runoff, and phosphorus concentrations vary strongly with weather events that drive surface flow and sediment transport (Koskelo 2008). Groundwater flow is much more stable than surface flow, so nitrate discharges are much less variable than phosphorus concentrations. The time it takes nitrogen to move through ground water to streams ranges from less than 1 year to over 50 years, with a median of 10 years (Phillips and Lyndsey 2003). This transit time contributes to a lag between changes in farm practices and nitrogen responses in receiving waters. Observing the nitrogen changes may require years of maintaining the farm practices and monitoring the responses (Hession et al. 2009).

Nitrogen changes can be estimated with inexpensive seasonal baseflow sampling of nitrate concentrations; seasonal measurements are sufficient because stream nitrate concentrations are relatively constant. Water discharge can be estimated within the monitored watershed or from measurements in nearby watersheds. Baseflow nitrate sampling can be applied cost effectively to many watersheds with differing rates of practice implementation. This option will be especially important if it is not possible to strongly direct practice implementation. In that case, numerous watersheds can be selected after implementation to give a set of study watersheds with widely different implementation rates of new practices (including watersheds with little or no new implementation). Studying greater numbers of watersheds also increases the confidence of extrapolating results to larger spatial scales.

Phosphorus discharges are harder to measure than nitrogen discharges because phosphorus is carried mainly on suspended particles. Particle concentrations are quite variable, and a few short episodes of high storm flow can account for much of the annual phosphorus discharge (Koskelo 2008). Continuous monitoring that captures both high and low flows is needed to measure phosphorus discharges, but it may be too expensive to do in many watersheds. Therefore, approaches that limit the number of watersheds to be monitored, such as before-and-after monitoring or paired comparisons, might be more suitable for automated sampling. Even with automated monitoring, years of monitoring data may be required to separate a phosphorus concentration response to implementation from the normal variability driven by storms and inter-annual climate variations.

The first workshop participants also considered soil phosphorus monitoring as an alternative to demonstrate the effects of conservation practices on phosphorus discharges. This method would measure soil phosphorus concentrations every 3 - 5 years in geo-referenced plots in farmed land with and without conservation practices. If conservation practices could be kept consistent for 6 - 15 years, this method could document reductions in soil phosphorus concentrations in fields receiving conservation practices compared to control fields. Soil phosphorus concentrations could also be measured before and after practice implementation. This method was not included in the final set of STAC recommendations for two reasons. First, it would be difficult to extrapolate the changes in soil phosphorus concentrations to predict effects on watershed discharges. Secondly, this is not really a watershed-scale measurement. Monitoring long-term changes in soil phosphorus under specific management practices in selected fields might be valuable, but it does not require a watershed approach.

The first workshop also discussed biological monitoring of the study watersheds. Biological monitoring was not included in the final list of recommendations because biological monitoring is more labor and cost-intensive than water quality monitoring and because it does not directly measure potential nutrient transfers to downstream waters (including the Chesapeake Bay).

There was also some discussion about using the watershed monitoring program to study the performance of specific conservation practices or mixes of practices. However, we recommend that such questions be addressed through specific rigorously defined research efforts at the sites of practice implementation. Different watersheds are likely to have different mixtures of conservation practices, which would make it difficult to infer the effects of any one particular practice by comparing watersheds. The watershed monitoring program should focus on documenting the effects of the implemented mixtures of conservation practices on stream nutrient transport.

Selecting Study Watersheds

The second workshop focused on identifying specific watersheds that might be suitable for the watershed-monitoring program. The monitoring designs from the first workshop were presented, followed by presentations of additional criteria that might be applied to identify the most suitable watersheds. Many of the selection criteria repeated ideas that had already been considered in the discussion of monitoring designs, but some new ideas were generated. The **selection criteria** considered are presented in the following list. Study watersheds should:

- have high nutrient and sediment yields to the Chesapeake Bay;
- be dominated by agriculture (for studying agricultural conservation practices, or dominated by the relevant source sector if studying non-agricultural practices)
- be small (10 - 40 km^2);
- be part of a set of watersheds that fulfills a monitoring design (above). All designs require study watersheds with significant new conservation practice implementation, but some designs also require watersheds with moderate or little new implementation
- have substantial implementation funding, farmer willingness and eligibility, and sufficient technical assistance and outreach to achieve substantial implementation where needed;
- have monitoring and verification to ensure that conservation practices are implemented properly;
- have high-resolution data on practice implementation (Table 1) and agricultural activities (Table 2) in an accessible database. Data disclosure should be resolved prior to any monitoring;
- have funding to sustain conservation practices for 5 - 10+ years;
- have information on relevant physical characteristics of the watershed (surface vs. groundwater, groundwater residence times);
- have baseline water quality data available. This could reduce start-up time for studies needing water quality data before practice implementation. On-going research programs would also be valuable;
- have interested watershed organizations (e.g., riverkeepers or citizens group); and
- have partnership possibilities with those planning and implementing the conservation practices.

Screening Methods

Ideally, the available data on watershed characteristics, agricultural activities, conservation practices, water quality monitoring programs, agency capacity, and other factors could all be summarized to help select candidate watersheds. This could involve relatively simple analyses of available mapped data using a geographic information system, such as that found in the CBP Chesapeake Online Adaptive Management Tool Kit (COAST). More complex watershed models (HSPF, SWAT, GWLF, PIHM), could also help to select watersheds and to predict likely water quality responses. The SPARROW model has already been applied in this way to produce the map of larger watersheds with high yields to the Bay (Fig. 1). The approach should be extended to describe smaller watersheds in the size range (10 - 40 km^2) recommended for the study watersheds.

Specific Candidate Study Watersheds

The second workshop also had presentations describing several specific study watersheds and possible advantages for monitoring responses to conservation practice implementation. Those presentations and other information were used to build a list of candidate watersheds, and then workshop participants voted for their top choices to produce a short list of candidate watersheds, which is included below. From list of candidates in each state, workshop participants voted on top three choices within each state. Table 3 summarizes the full list of watersheds presented and the watersheds within each state receiving most votes from the workshop participants.

Table 3. Preliminary list of watersheds to consider for monitoring water quality improvements from conservation practice implementation.

New York	**Pennsylvania**
Upper Susquehanna/Chemung River	Lower Susquehanna/Conewago Creek
	Lower Susquehanna/Mill Creek
Delaware	Lower Juniata/Kishacoquillas Creek
Nanticoke River	Conococheague Creek
	Lower Susquehanna/ Codorus Creek
	Lower Susquehanna/ Little Conestoga River
West Virginia	Middle Spring Creek
Opequon River	
Mill Creek/South Branch	
Capapon River/Lost River	
Maryland	**Virginia**
Choptank River	Shenandoah River/Smith Creek
Nanticoke River	Shenandoah River/Muddy Creek
Monocacy River	Rapidan River
Chester River/Chesterville Branch	Lower Dry River
Chester River/Morgan Creek	Linville Creek
Chester River/ Corsica River	Owl Run
Conococheague Creek/Opequon River	Nomini Creek
Langford Creek	Cooks Creek
Wye River	Long Glade
Sassafras River	Hazel River

Unfortunately, it was not possible during the workshop to assemble and review the data needed to evaluate the selection criterion using the objective methods described above, so the participant votes were based on incomplete information. Furthermore, many of the candidate watersheds are much larger than the 10 - 40 km^2 required for the actual study watersheds. The list is preliminary and is open to further analysis and refinement.

Post-Workshop Developments

In making final watershed selections, it is important to consider the latest information. Since the two STAC workshops were held, the following events have occurred that may provide additional information to help with selecting the watersheds:

- USDA NRCS revised their map of priority locations in which to target Year 2 of the Chesapeake Bay Watershed Initiative funding.
- USDA NRCS chose three "showcase" watersheds in which to focus concerted efforts to accelerate agricultural conservation with help from federal, state, and local partners to provide the necessary education, outreach, technical assistance, and monitoring. These watersheds are: Conewago Creek, PA; Smith Creek, VA; and the Upper Chester River, MD.
- USDA and EPA committed to a "Clean Waters – Thriving Agriculture Initiative" as part of President Obama's Executive Order in which they would more effectively align resources in these priority watersheds to drive nutrient and sediment reductions.
- USDA is working to develop a database of baseline conservation practice implementation from Farm Bill programs, state programs, and voluntary conservation farmers implement without federal and state cost share funding. This more complete database will identify locations of intense conservation practice implementation and therefore likely watersheds for detecting substantial nutrient and sediment reductions.
- EPA has solicited another round of NFWF Innovative Nutrient and Sediment Reduction projects for 2010, seeking projects that significantly accelerate nutrient and sediment reductions in small agricultural watersheds. Projects will be selected for funding in the summer of 2010.
- The USDA Conservation Effects Assessment Project (CEAP) Cropland National Assessment will be conducted in the Chesapeake Bay watershed (similar methodology to what was applied in the recent Upper Mississippi River Basin study, to be released shortly). This study will quantify the field-level and off-site environmental effects of agricultural conservation practices in the Chesapeake Bay Watershed through modeling and use of National Resource Inventory and NASS CEAP Survey data among other data.
- EPA has an active request to the Office of Management and Budget to use $1 million of the Chesapeake Bay Program increase in funding (the CBP received a $20M increase) for monitoring. Some of these funds could help monitor the effectiveness of conservation practices in small watersheds.
- The CBP's Management Board approved moving several hundred thousand dollars of funding from tidal watershed to non-tidal monitoring, which could help measure the effectiveness of conservation practices in small watersheds

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Workshop Web Sites

The agendas, presentations, and other information on the two workshops are available on the STAC website at the following locations:
http://www.chesapeake.org/stac/smallwtrshdmonitoring.html#workshop1
http://www.chesapeake.org/stac/smallwtrshdmonitoring.html#workshop2

Attendees at the First Workshop

Ken Carter, Virginia Tech-STAC
David Dirscott, Stroud Center
Mark Dubin, MAWP-CBPO
Tom Fisher, UMCES-HPL
Katie Foreman, UMCES-CBPO
Lamonte Garber, MSRA
Jake Goodwin, Chesapeake Research Consortium - CBPO
Tom Grizzard, Delaware DNREC
Cully Hession, Virginia Tech
John Jackson, Stroud Center
Tom Jordan, SERC
Jeni Keisman, UMCES-CBPO
Megan Lang, USDA-ARS
John McCoy, MD DNR
Kevin McGonigal, SRBC
Bruce Michael, MD DNR
Richard Mitchell, USEPA-OWOW
Glenn Moglen, Virginia Tech
Scott Phillips, USGS

Kristin Politano, UMCES-CBL
Kristen Saache Blunk, Penn State
Kevin Sellner, Chesapeake Research Consortium
Aisha M. Sexton, USDA-ARS
Scott Stranko, MD DNR
Ken Staver, UMD Wye Center
Peter Tango, UGSG-CBPO
Liz Van Dolah, Chesapeake Research Consortium
Michael Williams, UMCES
Don Weller, SERC-STAC
Gene Yagow, Virginia Tech

Attendees at the Second Workshop

Amanda Bassow, NRWF
Matt Baker, UMBC
Mark Bennett, Virginia Tech
Wade Biddix, NRCS-VA
Joel Blomquist, USGS
Claire Buchanan, ICPRB
Ann Carkhuff, EPA-RS
John Clune, USGS
Jana Davis, Chesapeake Bay Trust
Craig Derickson, USDA
Mark Dubin, MAWP-CBPO
Katie Foreman, UMCES-CBPO
Barry Frantz, Assistant State Conservationist
Jake Goodwin, CRC-CBPO
Rick Hoffman, VA DEQ
Susan Holdsworth, EPA-DC
Kristen Hughes, CBF
Ken Hyer, USGS-VA
Fred Irani, USGS
Tom Jordan, SERC
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Eileen McLellan, Environmental Defense Fund
Jack Meisinger, USDA
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Richard Mitchell, USEPA-OWOW
Matt Monroe, WVDA
Bill O'Donnell, Assistant State Conservationist
Scott Phillips, USGS
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Russ Perkinson, VA DCR
Paul Petrickjenko, Assistant State Conservationist
Royden Powell, MDA
Bill Richardson, EPA Region 3
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Scott Stranko, MD DNR
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